

Name _____

Rates of Reaction

Your Tasks (Mark these off as you go)

- ☐ Define key vocabulary
- ☐ Draw and interpret energy diagrams
- ☐ Identify the conditions necessary for a reaction to occur
- ☐ Describe the effects of a catalyst
- ☐ Investigate the factors that affect the rate of reaction
- ☐ Analyze your data
- ☐ Interpret your results
- ☐ Receive credit for this lab

☐ Define key vocabulary

Heat of Reaction

Activation Energy

Endothermic reaction

Exothermic reaction

Activated complex

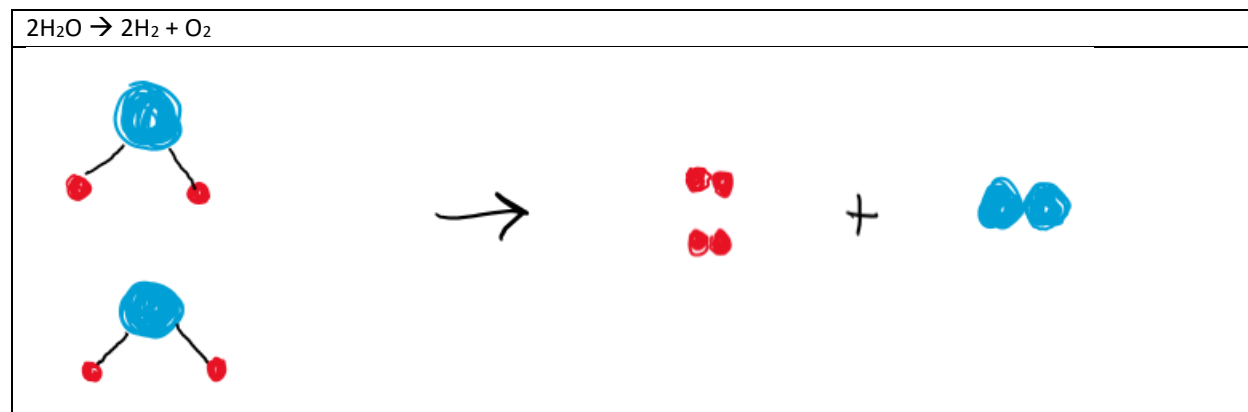
Catalyst

Effective collision

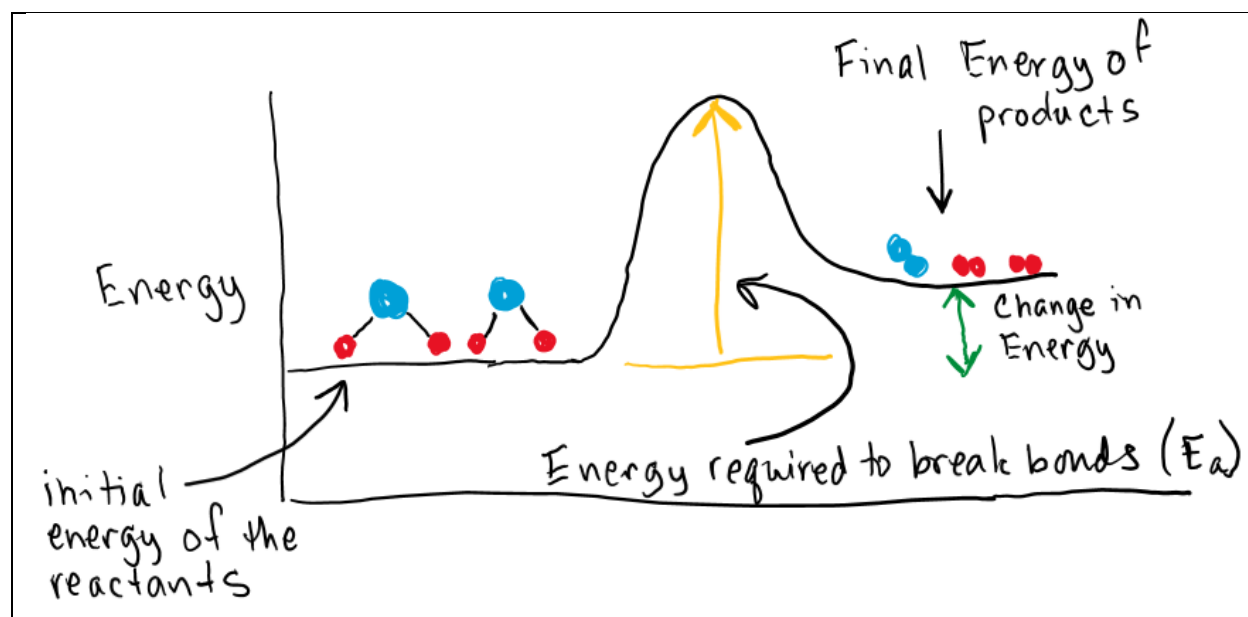
□ Draw and Interpret Energy Diagrams

A chemical reaction is the process of bonds being broken and bonds being formed. As an example, consider what happens if we decompose water into its elements. For the reaction to proceed we have to

1. Break the bonds holding the oxygen and hydrogen together in water (H_2O).
2. Make new bonds between oxygen atoms to form O_2 and Make new bonds between hydrogen atoms to form H_2 .



Just like breaking the physical objects around us requires energy, so too does breaking bonds at the molecular level. Therefore, for this reaction to proceed requires that we add some initial energy to break the bonds in water (H_2O). This initial energy required to get a reaction started is referred to as the **activation energy** (E_a). Once the bonds are broken the atoms can recombine to form oxygen (O_2) and hydrogen (H_2). This process of forming bonds releases energy. The flow of energy as this reaction proceeds is illustrated below,



The diagram above illustrates that we must go up (absorb) energy to break bonds. The process of absorbing energy is referred to as endothermic. Once the top of the activation energy hill is achieved, we go down (release) energy as the new bonds are formed. The process of releasing energy is referred to as exothermic. Finally, notice that the final energy of the products is higher than the initial energy of the reactants. That is,

$$E_{\text{products}} > E_{\text{reactants}}$$

The overall change in energy for the reaction can be expressed as follows. The triangle out front represents the “change” in energy.

$$\Delta E_{\text{reaction}} = E_{\text{products}} - E_{\text{reactants}}$$

Because the energy of the products is higher than the reactants, this means that the overall change in energy is positive,

$$\Delta E_{\text{reaction}} > 0$$

If the overall change in energy of reaction is positive, the reaction is said to be endothermic. If the overall change in energy of a reaction is negative, the reaction is said to be exothermic. This relationship is summarized below.

Endothermic	Product energy > Reactant energy	$\Delta E > 0$
Exothermic	Product energy < Reactant energy	$\Delta E < 0$

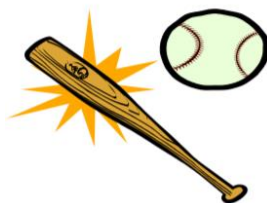
Draw and label energy diagrams depicting the following reactions.	
(a) $\Delta E_{\text{reaction}} = -30 \text{ kJ}$; $E_a = +50 \text{ kJ}$	(b) $\Delta E_{\text{reaction}} = +40 \text{ kJ}$; $E_a = +30 \text{ kJ}$
Which reaction is endothermic? Which reaction is exothermic?	
Which reaction requires the most energy to break the bonds in the reactants? Which reaction releases the most energy when the product bonds are formed?	

☐ Identify the conditions necessary for a reaction to occur

The collision theory states that a chemical reaction can only occur between particles when they collide (hit each other). But not all collisions result in a reaction. A collision that results in a reaction must have,

- Sufficient energy
- Proper orientation

In the picture below, the baseball bat represents Reactant A and the baseball represents Reactant B. A reaction will only be successful if the batter hits a homerun. If the batter does not hit a homerun, the reaction will be considered a failure. Now, read the four scenarios below and answer the questions that follow.



Scenario 1	The pitcher throws a fastball down the middle of the plate. The batter takes a mighty swing and totally misses the ball. The umpire yells, "Strike one!"
Scenario 2	The pitcher throws an off-speed pitch and the batter checks his swing. The batter just barely makes contact with the ball and it dribbles down in front of the batter's feet into foul territory. The umpire yells, "Foul ball; strike two!"
Scenario 3	The pitcher throws a curve ball that looks like it might catch the outside corner of the plate. The batter swings with all his strength, but the bat grazes the underside of the ball and the ball skews off to the right, flying into the crowd. The umpire yells, "Foul ball, still two strikes!"
Scenario 4	The pitcher throws another fastball down the middle of the plate. The batter swings and wallops the ball high into the air and the ball clears the center field wall that reads 410 feet. The umpire yells, "Homerun!"
Did a reaction take place between Reactant A and Reactant B in Scenario 1? Why or why not? Explain your reasoning in terms of the nature of the collision.	
Did a reaction take place between Reactant A and Reactant B in Scenario 2? Why or why not? Explain your reasoning in terms of the nature of the collision.	
Did a reaction take place between Reactant A and Reactant B in Scenario 3? Why or why not? Explain your reasoning in terms of the nature of the collision.	
Did a reaction take place between Reactant A and Reactant B in Scenario 4? Why or why not? Explain your reasoning in terms of the nature of the collision.	
Based on your responses to the previous questions and your reasoning, what insight has your team gained about the term effective collision?	

Hydrogen gas and iodine vapor combine to form hydrogen iodide gas, as shown in the equation $\text{H}_2 + \text{I}_2 \rightarrow 2 \text{HI}$. Using the representations shown below, draw a diagram to show an orientation for the reactant molecules that could produce an effective collision capable of producing two hydrogen iodide molecules.



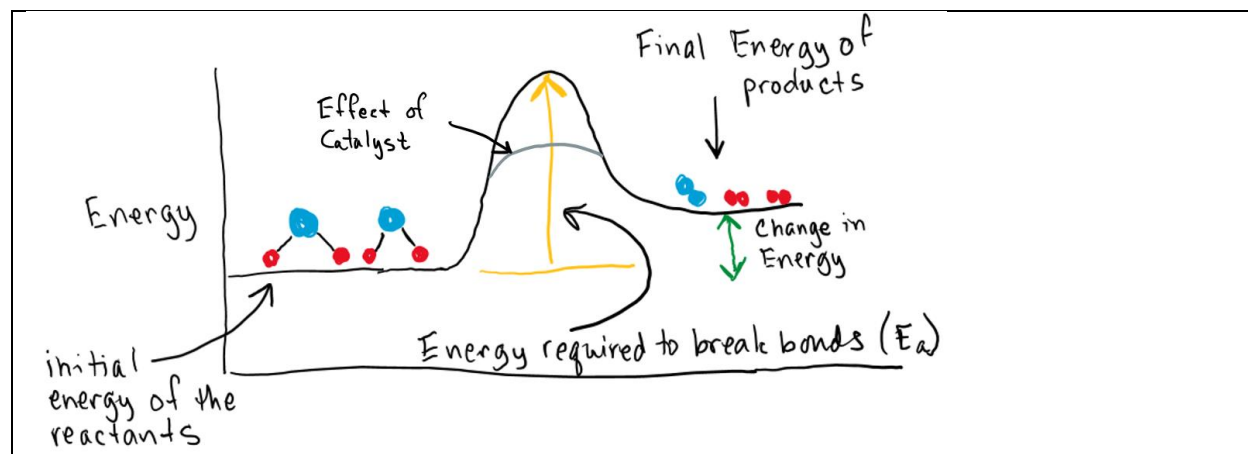
Hydrochloric acid reacts with aluminum to make Aluminum chloride and hydrogen gas,
 $6\text{HCl} + 3\text{Al} \rightarrow 2\text{AlCl}_3 + 3\text{H}_2$.

Using the representations shown below, draw a diagram to show an orientation for the reactant molecules that could produce an effective collision capable of producing the products.

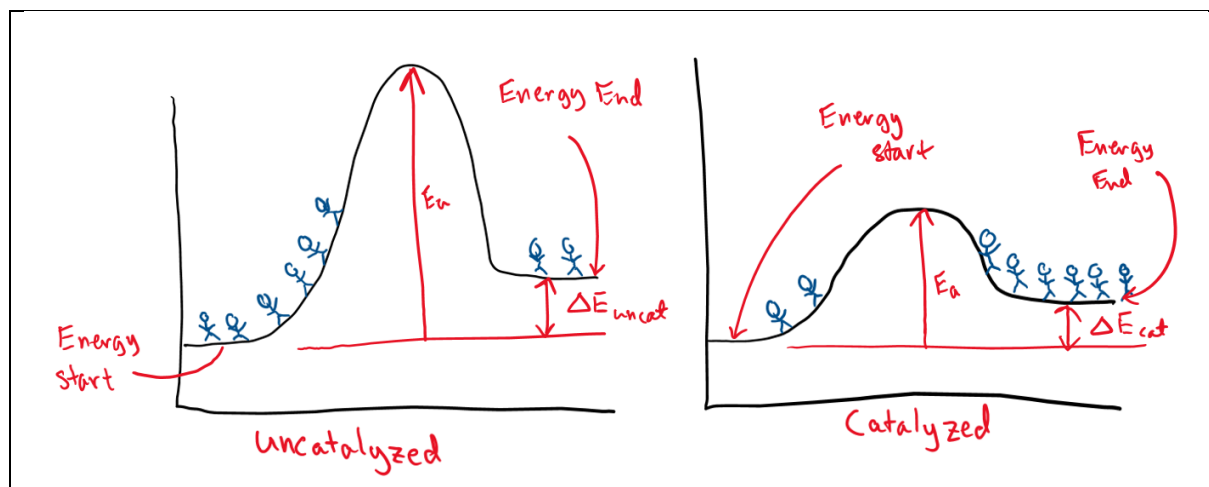


□ Describe the effects of a catalyst

A catalyst speeds up a reaction by providing an alternative pathway for the reactants to make the products. In terms of the energy diagram we looked at previously, catalysts lower the activation energy. This is illustrated below.



With a lower activation energy, more molecules can make over the activation energy hill, therefore increasing the rate the products are produced. To visualize this, imagine a bunch of people trying to hike over a mountain. If the mountain is very high, only the fittest hikers will make to the other side. If on the other hand we have a way to provide the hikers an alternative path, or lower the activation energy, more hikers will make it to the other side.



Based on the diagram above, below are some points regarding catalysts,

- Catalysts speed up the reaction by lowering the activation energy
- Catalysts do not change the overall energy given off or absorbed by the reaction. That is, ΔE , remains unchanged.

Consider the baseball analogy from before where a baseball bat represents Reactant A and the baseball represents Reactant B. A reaction is only successful if the batter hits a homerun. If the batter does not hit a homerun, the reaction will be considered a failure. What is an example of a catalyst you could add to this scenario to ensure more homeruns?



The decomposition of compound X is an elementary process that proceeds as follows:



The forward reaction is slow at room temperature but becomes rapid when a catalyst is added.

Draw the diagram of potential energy vs. reaction coordinate for the uncatalyzed reaction. On this diagram label:

- the axis
- the energies of the reactants and the products
- the activation energy, E_a
- the overall energy, ΔE

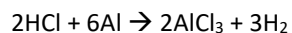
On the diagram indicate the change or changes that result from the addition of the catalyst.

Describe the effect, if any, a catalyst has on the following

- i. The energy of the reactants
- ii. The energy of the products
- iii. The overall energy, ΔE
- iv. The activation energy, E_a

☐ Investigate factors that affect the rate of a reaction

Aluminum foil reactions with hydrochloric acid according to the following reaction:



Think of two factors that would affect the rate of the reaction. Then in the space below predict how each factor would affect the rate of the reaction and why. Each prediction must be written using **COMPLETE SENTENCES**,

Factor 1:

Factor 2:

Refer to the equipment you have been provided. Then, in the space provided, write a procedure that will enable you to test the effect of one of the factors you stated above on the rate of the reaction between aluminum and hydrochloric acid. Your procedure **MUST** include (1) the data you plan to collect, (2) the equipment you plan to use, and (3) an appropriate number of trials (at least 4).

Create a data table below for organizing the data you proposed to collect in the procedures written above. The data you collect MUST include appropriate numbers of significant figures, units, and labels.

☐ Analyze your data

The data you collected must be presented in a format that communicates the effect of the factor you investigated. The presentation of your data must be done using Google Sheets. You may choose to present your data as a bar graph, a scatter plot, or... It is up to you! Your presentation of data MUST include appropriate units and clearly communicate the data you collected. Copy and paste your graph below.

☐ Interpret your results

Write a statement that indicates the purpose of this experiment.

In your own words, summarize what you did in order to accomplish the purpose. Be specific!

Summarize your findings. Discuss the data you collected along with how the graph you created either support or refute your predictions.

Discuss two sources of error and the effect each may have had on your results.

☐ **Receive Credit for this lab**

Submit your completed lab to receive credit.